BIO-MEDICAL WASTES DISPOSAL INCINERATOR SYSTEMS - UNDERSTANDING, CRITERIA AND ANALYSIS FOR COMPARATIVE SELECTION.

Preamble

The Bio-medical waste (Handling and Management) Rules, 1998, promulgated by Ministry of Environment & Forests (MoEF) permits Incineration of selected categories of Bio-Medical Wastes (BMW) as one of the Treatment & Disposal options. The permissible categories of wastes for Incineration included are Category No.1 (Human Anatomical Waste); Category No.2 (Animal Waste); Category No.3 (Microbiology & Biotechnology Waste); Category No.5 (Discarded Medicines and Cytotoxic Drugs); and, Category No.6 (Soiled waste - items contaminated with blood, and body fluids). The Standards for BMW Incinerators shall comply with MoEF Rules as per Schedule V which includes: a) Operating Standards, and, b) Emission Standards, and these are prescribed as per Central Pollution Control Board (CPCB) guidelines. The Rules permit these Incinerators, meeting with operating standards requirements, to be operated on-site or as well as off-site. Since then many BMW Incinerators have been, and are continuing to being, installed and operated on-site, whilst very limited off-site centralised Incinerator plants have been set-up. Though these BMW incinerators have been installed in accordance with the 'letter-of-the-law', they certainly are not being operated in the 'spirit-of-the-law'. This is a major environmental and public health concern. Incineration process is rather a final waste disposal option to be compared with other disposal options such as sanitised landfill and deep burial. Incineration should not be considered as a waste treatment option, and is not a comparable waste treatment option such as steam Sterilizer / autoclave / hydroclave, Chemical disinfection and Microwave system.

The objective of this paper is not to encourage the usage of incinerators where economic and safe alternative preferences are available for treatment and disposal of BMW. But, where the decisions have been made to opt for BMW incinerator, then this paper should enlighten the Selectors, Decision makers, Operators and other stakeholders in proper understanding and criteria for optimum selection of Incinerator system. A poor selection of Incinerator system could only result in an ongoing health hazard or scrapping off a huge investment, in short span of time, made into incineration system. The paper is confined to some of the selected basic understanding of BMW incineration that will be useful in proper selection as well as proper operation of BMW incinerator system. However, the incinerator operation is not covered in this paper, and interested readers may refer to Technical Papers, Hand Books, US EPA Guidelines and various articles referenced at the end of this paper for further reading for implementations.

The experience has shown that the purchasers and operators of incinerator systems, have more often than not, know very little about the fundamentals of Incinerators and intricacies and hazards involved with Bio-medical waste incineration, which otherwise would have helped them in opting for, selecting and operating a better choice of incineration system. It is not intended that this paper covers high technical jargon nor does it go into the depth of this very vast subject, but to arouse adequate interest to make use of proper selection of incineration system with the design selection parameters listed in this paper. This paper should interest users to refer to hand books and specialists in Incineration business.

Fundamentals of Incineration

'Incinerate': In Greek it is 'Burn to ashes'. It is also known as Thermal Oxidation. The other forms of thermal destruction include Pyrolysis and Starved Air Combustion [(1) CLAVIN R. BRUNNER]. Incineration is a process by which combustible materials are burned, producing combustion gases and, non-combustible residue and ashes [(2) USEPA O&M HMWI]. Incineration is combustion or burning process, involving the chemical reaction of combustible waste materials with air, in which the primary purpose is the destruction and reduction, in size and mass, of the combustible material. A secondary purpose may be the sterilization or destruction of pathological or hazardous waste materials [(3) California EPA Compliance Assistance Program on Incinerators].

Combustion is a rapid chemical reaction process between oxygen (available in air) and combustible elements (such as carbon or hydrogen). Good combustion can produce invisible gases. Poor combustion can produce acrid smoke. Incineration process is to convert solid and liquid waste to Gas to allow combustion process to take place. No combustion process occurs instantly. The incineration process involves steps of Heating and drying; Volatilisation; Ignition; and heat release. The greater the air (oxygen) supply, the greater likelihood of complete burnout. The **Temperature** required for Ignition of gases to take place varies with that of the combustible material being incinerated. For gases from Paper the ignition will take place at 232 C; for gases from Charcoal the ignition will take place at 350 C; for gases from Coal the ignition will take place at 480 C; for gases from Carbon monoxide the ignition will take place at 650 C; for gases from Methane the ignition will take place at 630 C to 750 C. The greater the Air Supply, there is the greater likelihood of complete burnout. The amount of excess air required varies with the nature of combustible material. For Gaseous wastes the excess air required varies between 110% to 115%; for Liquid wastes the excess air required varies between 120% to 130%; For the Solid (medical) wastes the excess air required varies between 175% to 300%; For combustion to take place, besides Temperature, the air (oxygen) has to adequately mix with the hot gases from heated wastes, and such a mixing process is achieved through sufficient **Turbulence** by means of mechanical and manual mixing. Turbulence in secondary chamber assists complete combustion in

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shorter time. Besides Temperature and Turbulence requirement for combustion, the third important parameter is the 'Solids Residence Time' required for burnout of solids in the primary chamber producing combustible gases; and the 'Gas Retention Time' in the Secondary chamber, which ensures that the gas discharge from it controlled at 871 C to 1093 C. Usually the gas retention time in the secondary chamber is designed for 1-second to 2-second. You will therefore commonly hear about the 3-T's of combustion: Temperature, Turbulence and Time. For control of complete combustion and adequate incineration, the 3-T's have inter relationship which has to be balanced.

'Retention Time' cannot be controlled directly once the incinerator is designed and built. Residence time is a function of Chamber Volume and Volumetric Flow Rate. Planning for increased 'Retention Time' would result in Increased Size of an Incinerator and thereby resulting in Increased Capital Cost and Increased operating Heat loss. Indirect control of retention time is achieved by: controlling waste feed rate; by controlling Temperature within Incinerator.

'Temperature': Even though Temperature at some location is high, if sufficient oxygen (air) and Turbulent mixing are not provided, no reasonable amount of Residence Time can achieve complete combustion. Temperature can be easily achieved. 'Retention time' and 'turbulence' are more difficult to control.

'Incomplete Combustion': The reasons for it are:

- Temperature: Not high enough in Secondary chamber.
- Oxygen: Not enough (air starvation).
- Mixing (Turbulence): Not enough.
- Residence Time: Insufficient in the Secondary chamber.
- Waste Feed Rate: Excessive.

'Combustion Air': Too much combustion air may be just as bad as too little air, as it will cool the combustion reaction and cause incomplete combustion. Too much excess air may make it necessary to burn auxiliary fuel in order to maintain temperature.

'Hospital Waste Characteristics': Understanding of waste characteristics is of prime importance as the basic purpose of Incinerator is for safe and efficient destruction of these wastes. Hospital wastes are heterogeneous mixtures of general refuse; laboratory & pharmaceutical chemicals and containers; and, pathological wastes. Heat Content and moisture content of waste being charged to the Incinerator, will affect the operators ability to maintain good combustion conditions in the incinerator without the use of auxiliary fuel. Incinerators are to be sized based on Heat Liberated from hospital waste in combustion process. Two major impacts that moisture has on the combustion system are increased volumetric flow and reducing Residence Time of the combustion gases. Halogentaed plastics, such as polyvinyl chloride, will produce acid gases such as HCl. The presence of chlorinated wastes also may contribute to the formation of Toxic polycyclic organic material such as dioxins and furans under poor operating conditions. Segregation, removal and control of unwanted waste components for Incinerator system from the Hospital waste stream is of utmost importance. There are statutory regulations to this effect.

Incinerator Construction

The basic Incinerator system construction has following components.

- **Waste Feed**: The waste can be manually fed, by mechanical arrangement such as feed trolley, or by an automatic feed arrangement. Manual waste feed is the most commonly practiced for small and medium capacity on-site incinerator, and its capital cost is low, but the operating efficiency is reduced. The waste bag size should match with the waste feed door size of the incinerator.

- **Primary Combustion Chamber**: The waste is first fed into the primary chamber where the vaporisation of volatile matter takes place. The waste is ignited and moisture driven-off by the aid of auxiliary burners. The waste is placed on the **Grate** in the primary combustion chamber. The air (oxygen) supply is made by means of a Forced Draft (FD) fan. The size of the chamber volume and the grate area some of the factors which determines the incinerator capacity.

- **Secondary Combustion Chamber**: The hot volatile and combustible gasses liberated from waste in the primary chamber, passes through the ducts into the secondary chamber. Complete burnout of combustibles should take place in this secondary chamber by means of secondary burners. The hot gases may be allowed to pass through a tertiary chamber where it will allow heavy particulate matter to settle down.

- **Ash Removal**: the ash collection chamber is located at the bottom of Primary chamber, and the provision for ash removal from secondary chamber is also provided for. The holding capacity of the ash collection chamber determines the operating hour capacity of the incinerator, after which the ash chamber has to be cooled for removal of ash. Ash collection chamber of large holding capacity increases the overall size of the incinerator and thereby its cost.

- **Gas cleaning system**: The hot gases discharged from the secondary / tertiary chamber are latter are passed through dry particulate separators and / or Wet scrubber system. The different types and varying efficiencies of Gas cleaning system would determine the cost of the system.

- **Chimney**: The cleaned and cooled gases from the gas cleaning system are discharged into a chimney. The gases are discharged by means of an Induced drafted fan. The cost of the chimney is determined by the construction standards. For tall chimneys (of 30 meter height) there is a considerable cost involved with regards to laying of chimney base support civil foundation work.

- **Monitoring & Control**: Monitoring and control measures are needed for incinerator combustion control as well as for environmental monitoring and control.

- **Incinerator Building**, housing the Incinerator as well as the gas cleaning system, should be very well ventilated to ensure that the incinerator combustion in not starved due to insufficient rate of combustion air (oxygen). The overall size of the incinerator building is a significant cost component of the Incinerator plant costs.

Incinerator Types

There are various explanations to various types of incinerators, and they can be grouped under: i) CATEGORY WISE: Batch feed type, Intermittent type, and, Continuous feed type; ii) CAPACITY WISE: Small, Medium, and Large; and, iii) DESIGN WISE: Single chamber, Multiple chamber, Controlled air, and Rotary Kiln.

Batch Type: In this type a fixed quantity of waste is fed into the incinerator. The incineration cycle lasts for a period of six to eight hours. These are usually of small capacity having a single chamber, fixed grate. They usually operate at temperature of 600 C to 800 C. The waste is ignited and burned with oil fired or by Electric heating. They are such that neither waste charging nor ash removal can occur during combustion. Over many decades, these types of incinerators were widely and successfully used in U.K, Europe and North America, for Hospital waste Disposal. However these types of incinerators do not meet the New Operating Standards and do not meet with the New Environmental Standards. Modern Batch type incinerators are of two-chamber construction, having high temperature operation of 800 C to 1000 C, combustion efficiency of 99.9999%, invisible smoke and meet with the New environment emission standards.

Intermittent Type: In Intermittent Type of incinerators the waste is fed at intermittent intervals of every 10 to 15 minutes. They are usually of multiple chamber design (primary, secondary and tertiary) and operate at 800 C to 1000 C. They are of the fixed grate type and the ash build up has to be manually pushed into the ash collection chamber below the primary combustion chamber. They are suited for small and medium capacity incineration. The incinerator operating cycle is limited to the holding capacity of the ash collection chamber. Larger the ash collection chamber, longer is the operating cycle, thereafter the incinerator has to be cooled, ash removed before the next incinerator cycle starts. They usually operate for 12 to 14 hours before final burn down. These types of incinerators have been widely used in India in the 600 C to 800 C operating range. The current incinerators being installed are constructed for 800 C to 1000 C operations, meeting with the Central Pollution Control Board (CPCB) standards. They are limited to intermittent operation by virtue of the manual movement and removal of ash.

Continuous Type: In these types of incinerators the grate is of moving type, which progressively moves the ash into the ash collection chamber. The ash removal is continuous by an automatic removal system. These systems are more economical for large capacity incinerators. They are available in Multiple Chamber or Rotary Kiln designs.

Small Capacity: Maximum design waste burning capacity is less than or equal to 90 kg/hour (200 pounds per hour).

Medium Capacity: Maximum design waste burning capacity is from 90 kg/hour (200 pounds per hour) to 220 kg/hour (500 pounds per hour).

Large Capacity: Design waste burning capacity is above 220 kg/hour (500 pounds per hour).

Single Chamber: Incinerators used for small quantity batch incineration for on-site waste disposal. It has features that of the 'Batch type' incinerators described above.

Multiple Chambers: Incinerator described in 'Incinerator Construction' above, is that for a typical multiple chambers incinerator.

Rotary Kiln: These incinerators are widely used in the treatment of hazardous waste. They are versatile and are suitable for most types and forms of waste including solids, sludge, liquids, and gases. Later these systems have been applied to the burning of medical waste. A rotary kiln incinerator is a cylindrical primary combustion chamber, which rotates about a horizontal axis. It is tilted at a slight incline to the horizontal from 40 to 80 mm per meter of length. It is rotated slowly, approximately 1 revolution per minute. Waste is charged at the upper end of the kiln and its rotation moves the waste slowly towards its opposite end. Waste will burn within the kiln and by the time the burning waste has reached its far end it will be burned out to an ash and will be discharged to an ash sump. A separate secondary combustion chamber is located downstream of the kiln to complete combustion of organics in the off-gas, providing Temperature, Time and injecting air to obtain the Turbulence required for good combustion. The Rotary Kiln incinerators are not being used in India for Bio-medical waste disposal.

Incinerator Design Aspects

Following design aspects will enable you to check and compare during the competitive selection of Incinerator offers.

1. Length-to-Width Ratio of Primary Combustion Chamber:

a.) For Multiple chamber incinerator of capacity less than 230 kg/hour is 2.0 to 1

b.) For Multiple chamber incinerator of capacity greater than 230 kg/hour is 1.75 to 1

c.) For Multiple chamber incinerator of capacity less than 340 kg/hour is 1.65 to 1

d.) For Multiple chamber incinerator of capacity greater than 340 kg/hour to less than 907 kg/hour is 1.1 to 1

2. Grate Loading

a.) Acceptable Grate loadings for incinerator capacity 11.3 to 340 kg/hour capacity range from 73 to 122 kg/(m^2h).

b.) Acceptable Grate loadings for incinerator capacity greater than 340-kg/hour capacity range from 122 to 146 kg/(m^2h).

c.) A number of incinerators have designed for grate loadings of 244 to 342 kg/(m^2h).

3. Arch Height and Grate Loading Relationship

Optimum Arch height and Grate Area can be estimated. The relationship between arch height and grate area can be calculated from the empirical equation:

Arch Height in meter $(H_A) = 0.9643 (A_G)^{4/11}$

Where, A_G is the Grate Area of horizontal cross-sectional area of the ignition (Primary) chamber in square meter.

4. Optimum Design Velocities for Gas Flow:

GAS FLOW PATH	VELOCITY IN M/S
Flame Port	13.7 to 19.8
Mixing Chamber	6.1 to 10.7
Curtain-wall Port	3.0 to 4.6
Secondary Combustion Chamber	Less than 3.0

The above velocities enable to maintain required Turbulence required for combustion and incinerator operation.

Conclusion:

The choice of selection of the type of incinerators available in India is very limited. The above guideline and information available from the below listed reference list would enable administrators to take an educated purchase decision.

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